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Physico-chemical Properties and Biochemical Composition of Physalis (*Physalis pubescens* L.) Fruits

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ABSTRACT

Ground cherry (*Physalis pubescens* L.) is one of the most promising exotic fruits, which can be used for developing interesting functional products. This paper reports the biochemical composition of physalis fruit and juice. The pulp was yellowish or orange with a yield of 64%. The pulp and fresh juice had a light sweet and acidic taste (pH 3.7). The titratable acidity was 1.23, polyphenols, 82 mg and vitamin C, 32.7 mg per 100 g of fruit. Physalis fruits and its juice were rich in carotenoids (69.6 µg/g and 70 µg/mL, respectively). Juice had high levels (in mg/100 mL) of minerals such as phosphorus (578), potassium (1196), zinc (2.4) and boron (1). Essential amino acids as Leucine, Lysine, Isoleucine, Valine and Tryptophan were either higher than those recommended by FAO/WHO/UNU (1985). Phenolics and other polar compounds were analyzed and indentified in juice. The antimicrobial activity of methanolic extracts of juice was significant against *E. coli* O157:H7 and *Bacillus subtilis*, complete against *Fusarium solani* and had no effect against *Candida albicans*.

Keywords: antimicrobial effects, ground cherry, nutritional evaluation, physico-chemical composition

INTRODUCTION

Throughout history humans have used some 3,000 plant species for food. The recent tendency has been to exploit fewer species and today, only around 20 species supply most of the world's food. Many beneficial plant species have been underused (Vietmeyer 1991). Among unexploited tropical fruits, ground cherry or husk tomato (*Physalis pubescens* L.) is very promising (El Sheikha 2004). Physalis is an important genus of the Solanaceae family (ITIS 2003) The Solanaceae family contains about 100 species of annual and perennial herbs (Willis 1966). It is native to tropical and subtropical America and is widely distributed throughout the world.

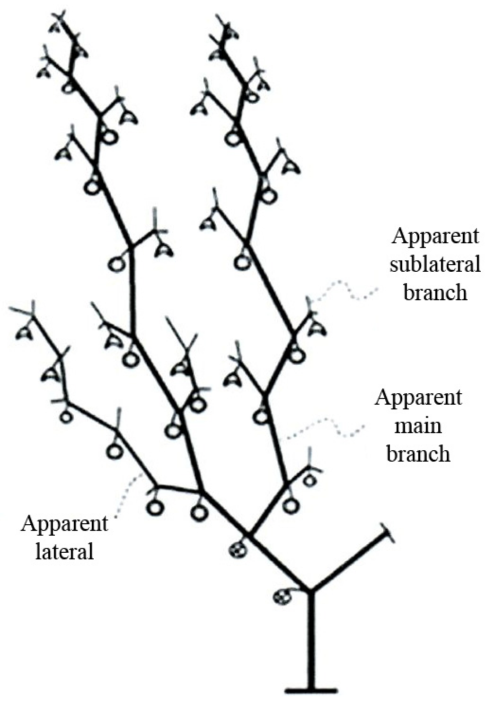

Fig. 1 ***Physalis pubescens*** **L. is a low-growing, annual herbaceous shrub plant that could growth up to 0.45 m.**

Fig. 2 Ground cherry (*Physalis pubescens* L.) in opened calyx. The Egyptian fruit is a berry (1.90-2.0 cm) wide, with smooth, waxy, orange-yellow skin and juicy pulp containing numerous small yellowish seeds. Photo: Aly El Sheikha.

Physalis is a low-growing, annual herbaceous shrub plant that can grow up to 0.45 m and has a shallow, fibrous root system (**Fig. 1**). The plant has ovate-shaped leaves 4-9 cm and yellowish dark-spotted, bell-shaped flowers, propagated by seeds (germination in 8-15 days). The mature berry has a golden yellow skin, with many minute seeds in a juicy pulp which is sweet, and tangy (**Fig. 2**), resembling Chinese lantern (Fouqué 1972). It is fairly adaptable to a wide variety of soils light (sandy), loamy and clay and requires well-drained soil. It could grow on semi-shade or no shade, dry or moist soil. So, Physalis can be sown in arid environmental conditions and people may be encouraged to propagate it in new reclaimed lands, especially the desert regions (Randall 2001). A single plant may yield up to 0.5 kg fruits and carefully tended plants can provide 20-33 tons/ha (Dremann 1985).

Fruits can be stored for several weeks if left in the calyx, additionally it could be stored in a container and kept in a

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dry atmosphere for several months and it also freezes well (Coffey 1993). Physalis is now considered as a fruit for backyard gardens or for children to pluck and eat; however, they do carry prestige in some international markets. Europeans often pay premium prices for the fruits, which are dipped in chocolate or used to decorate cakes and pies. It is an interesting ingredient for salads, cooked dishes, deserts, jam and natural snacks (Facciola 1990). Moreover, many medicinal properties have been attributed to Physalis as the whole plant, including antipyretic, depurative, diuretic, pectoral, and vermifuge. A decoction is used in the treatment of abscesses, cough, fevers or sore throat (Duke and Ayensu 1985). The pulp is nutritious, containing particularly high levels of niacin and a medium amount of vitamin A. Nowadays, physalis is included in the priority list of many governments' horticulture and fruit export plan. It is relatively unknown in importing markets and remains an exotic fruit. It is exported from several countries including Colombia, Egypt, Zimbabwe and South Africa, but Colombia stands out as one of the largest producers, consumers and exporters (USDA, GRIN and NRCS Database 2006). Whence, physalis occupies second position in the priority list of 15 exportable fruits: exports of this crop in 2004 were worth 14 millions USD (Bayer Crop Science 2006). In Egypt, physalis has been known for a long time. Recently, economical importance of physalis is rising, due to its high acceptance in the local consumption, achieving a great success in Arabic and European markets (El Sheikha 2004).

Previous work on physalis has focused on general proximate composition of the fruit which was used as an excellent source of niacin (Watt and Merrill 1963). Thereafter, isolation and characterization of several bioactive withanolides from whole plant were reported (Ahmed *et al.* 1999). No data about physalis fruit juice is yet available.

In this paper, the chemical composition and selected physico-chemical parameters of physalis fruit and juice including phenolics, flavonoids, carotenoids amino acids and other polar compounds are reported. In addition, extracts of fresh physalis juice were tested for their antimicrobial effects against *Esherichia coli* 0157:H7, *Bacillus subtilis*, *Candida albicans* and *Fusarium solani*. Our objective was to determine its nutraceutical and economical potential so that it can be developed as a commercial crop.

MATERIALS AND METHODS

Biological material

Ripe *Physalis pubescens* L. fruits were obtained in 2004 from local growers at Arab El-Rawshda village, Toukh, Qalyoubia Governorate which is one of the Delta Governorates located in north of Egypt. Intact fruits were carefully selected according to the degree of ripeness measured by fruit colour (brilliant orange) and the pH value of the pulp (pH 3.6) as well as total titratable acidity (1.23%). The fresh fruits were analyzed immediately after harvesting.

Methods

Extraction of fresh physalis fruit juice

Physalis fruits were de-husked manually, sorted to select the ripe and intact ones and graded depending mainly on their color, then washed. Then, the fruits were pulped by using a fruit pulper (Braun, Model 2001, Germany) for juice extraction. Juice was filtrated in a cheese cloth to separate seeds and skins and the fresh fruit juice was analyzed directly after production.

Chemical and physicochemical properties of fresh fruit and juice

Sizes of fruits were measured using a Vice Caliper (Model A2, Germany) with an accuracy of 0.1 mm. The density was calculated as mass/volume of a fruit (Khurmi 1982). Juice yield was calculated as obtained juice/100 g of fresh fruits × 100 (Omar 1998). The colour of raw juice samples was assessed by using a Lovibond Tintometer (Model E, Salisbury, GB) (Ranganna 1979).

Moisture, crude protein (%N × 6.25), ether extract, carotenoids, total and reducing sugars, minerals and total ash were determined (AOAC 1995). pH was measured at 25°C. Total acidity was titrated with 0.1 N NaOH using phenolphthalein indicator and was expressed as anhydrous citric acid/100g of sample. Total soluble solids (TSS) were determined using Abee-Refractometer at 20°C (Carl Zeiss, Germany). Ascorbic acid was estimated by the colorimetric method of Folin-Ciocalteu at 760 nm (Bajaj and Kaur 1981). Total sugars were extracted from samples by using 80% ethanol and reducing sugars were determined (as glucose) colorimetrically at 490 nm. The difference between total and reducing sugars was recorded as non-reducing sugars. Total polyphenolic substances were measured (as tannic acid) colorimetrically at 640 nm by Folin-Ciocalteu (Dóka and Bicanic 2002). Thirteen important minerals were analyzed. Total phosphorus was determined colorimetrically at 660 nm (Taussky and Shorr 1953), sodium and potassium contents were estimated by Flame Photometer (Jenway PFP 7, GB). Others minerals were determined by Atomic Spectrophotometer (Perkin Elmer 932AA, Australia). Pectin substances were determined (Egan *et al.* 1981). Sugar/acid ratio was calculated as total soluble solids/titratable acidity (Fuleki *et al.* 1995; Lacey *et al.* 2001). Crude fibers were determined on defatted fresh fruits by the modified enzymatic-gravimetric method (Prosky *et al.* 1988; AOAC 1995). Amino acid compositions were determined on Beckman Amino Acid Analyzer 119 CL (GB) (Moore and Stein 1963) after hydrolysis with 6 N HCl containing 0.1% mercaptoethanol at 100°C for 24 h. Tryptophan was quantified on a $Ba(OH)_2$ hydrolysate by colorimetric method (Miller 1967).

Polyphenols extracted from raw juice were fractionated by HPLC (HP 1100, Germany) under the following conditions: injection volume10 µL, Column: Hypersil BDS-C18, 5 µm (150 × 4.6 mm; Altech, USA), UV Detector at 254 nm, Mobile phase: Solvent A: Acetic acid/Acetonitrile (0.5/99.5, v/v) and solvent B: acetic acid/distilled water (0.5/99.5, v/v) with a flow rate of 0.3 mL/min at 25°C. The Standard curve was prepared by mixing equal weights of pyrogallic, hydroquinone, resorcinol, catechin, phenol, rutin, myricetin, quercetin, kaempferol and the gallic, protocatechuic, para-hydroxybenzoic, chlorogenic, vanillic, para-coumaric, ferulic, salicylic, ortho-coumaric, coumaric, cinnamic acids.

Evaluation of protein quality by computation

Chemical score (CS), which is based on the amount of most limiting amino acid present in the test protein relative to the amount of that amino acid in the reference egg protein, was calculated using the equation (Block and Mitchel 1946):

$$CS = 100 \times \text{Min}\left[\frac{a_i}{a_{i,ref}}\right]$$

where a_i is the concentration of each essential amino acid in the sample (g/100g protein), $a_{i,ref}$ is the concentration of each essential amino acid in the reference (FAO/WHO/UNU 1985) and Min is the minimum ratio of (a_i / $a_{i,ref}$).

Protein quality was determined by protein efficiency ratio (PER) or weight gain/g protein intake. PER was estimated (Als—meyer *et al.* 1974): PER = -0.468 + 0.454 [Leucine] – 0.105 [Tyrosine].

Essential amino acid index (EAAI) was calculated (Oser 1951) taking into account the ratio of EAA in the test protein relative to their respective amounts in whole egg protein:

$$EAAI = \sqrt[10]{\frac{aa_1}{AA_1} \times \frac{aa_2}{AA_2} \ldots\ldots\ldots\ldots \times \frac{aa_{10}}{AA_{10}}}$$

where *aa* is the concentration of each essential amino acid in the sample (g/100g protein) and *AA* is the concentration of each essential amino acid in the reference (FAO/WHO/UNU 1985).

Antimicrobial activity

Bacillus subtilis, *Fusarium solani*, *Escherichia coli* O157:H7 ATCC 43695 and *Candida albicans* ATCC 10239 were supplied by the Microbiology unit of National Research Centre, Cairo, Egypt.

The disc diffusion method was employed for the determination of antimicrobial activities of methanolic polyphenolic extracts obtained from raw juice (Cowan 1999; Cavanagh *et al.* 2001). Polyphenolic extracts were diluted in 95% methanol to obtain 15 and 30% (w/v) concentrations. The microorganisms were inoculated on the surface of Muller-Hinton agar Petri dishes and the paper discs (6 mm, Whatman No.1), impregnated with the test substances and placed in the centre of the inoculated Petri dishes. The inhibitory effect of the 95% methanol alone was also tested by placing a saturated disc on each inoculated Petri dish. Petri dishes were incubated at 37°C for 24 h for bacteria and at 30°C for 48 h for yeast and mold. Zones of inhibition were calculated by measuring diameter in mm (including disc). All tests were conducted in triplicate.

RESULTS AND DISCUSSION

The average weight of the fruits was 3.71 g (**Table 1**), which represented 297 fruits/kg. Their average diameter was 1.9 cm. The percentage of husk on raw fruits was 5.6% and pulp yield after dehusking was 94.4%. The extracted juice represents 63.9% while the seeds and skins together amount were 36.1% of the whole fruit. Due to this relatively high percentage of seeds and skins, the juice/seeds and skins ratio was relatively low (1.8/1). Abou-Gharbia and Abou-Tour (2001) found similar results for the variety *Physalis pruinosa* 4.1 g for the average weight of fruit; 205 fruits/kg, 2.2 cm diameter; 6.42% husk; 93.58% yield after dehusking; 65% juice extracted and 35% seeds and skins. In addition, they found for juice: seeds and skins ratio of 1.86/1.

Physalis fruits contained 81.3% moisture (**Table 2**), as also reported for *P. pruinosa* fruits 80.7% (Abou-Gharbia and Abou-Tour 2001) and were in the same range as reported by Watt and Merrill (1963), Morton and Miami (1987), Cantwell *et al*. (1992) and USDA (2006), who found that physalis fruits (*P. pubescens*, *P. peruviana*, *P. ixocarpa* and *P. ixocarpa*) contained 85.4, 78.9, 80.2 and 91.6% moisture, respectively. This moisture content was higher than in other fruits as avocado 73.2% and banana 74.9% but lower than that in strawberry 90.9% and watermelon 91.4% (USDA 2006).

The Total Soluble Solids (TSS) value was lower than those reported for other fruits; namely raspberry (13.9%), apple (14%) blackberry (15.4%), black cherry (18.7%) and black currant 19.7% but higher than that for strawberry (10.2%) and tomato (4.5%) but close to that of pineapple (13.5%) (Kirk and Sawyer 1991). The difference between total solids and total soluble solids is mainly due to the insoluble pectin and fibers. The total solid content of Physalis fruit represented 18.85%, which was lower than that mentioned by Abou-Gharbia and Abou-Tour (2001) for *Physalis pruinosa* fruits (19.29%).

Table 1 Physical, technological and physico-chemical properties of physalis fruits.

Property	Value
Physical properties *	
Number of fruits per kilogram	297 ± 6.0
Fruit average weight (g)	3.71 ± 0.74
Average diameter (cm)	1.90 ± 0.16
Fruit density (g/cm^3)	1.10 ± 0.07
Technological properties *	
Husks %	5.6 ± 0.9
Pulp yield after dehusking %	94.4 ± 0.5
Extracted juice %	63.9 ± 2.4
Seeds and skins %	36.1 ± 2.4
Extracted juice/seeds and skins ratio	1.8/1 ± 0.2
Physico-chemical properties **	
Total solids (TS) %	18.65 ± 1.59
Total soluble solids (TSS) %	13.46 ± 0.05
pH-value	3.74 ± 0.02
Total titratable acidity (as anhydrous citric acid) %	1.23 ± 0.01
Sugar/acid ratio	11.27/1 ± 0.11

* Values are means of 12 measurements ± standard deviation.
** Values are means of 3 determinations ± standard deviation.

The fruit was acidic with a pH of 3.74 (**Table 1**) due to the presence of most organic acids in free forms. It was similar to those reported for *P. ixocarpa* (Cantwell *et al.* 1992) and for *P. pruinosa* (Abou-Gharbia and Abou-Tour 2001) and its was close to cherry, peach and kiwifruit (pH 3.2-3.6) and lower than of other fruits like tomatoes (4.3), figs (5.0) and carrots (5.2) (Joslyn 1970).

Total titratable acidity (TA) of fruits reached 1.23%. This TA value is similar to those reported by Cantwell *et al.* (1992) for *P. ixocarpa* as well as Abou-Gharbia and Abou-Tour (2001) for *P. pruinosa*. In addition, Joslyn (1970) reported that the TA value of physalis was lower than that found in apple (0.65), banana (0.27), cherry (1.06%), grapefruit (1.16%), orange (0.8%), peach (0.46%), plum (0.79%), pineapple (0.62%) and strawberry (1.02%). On the other hand, Kirk and Sawyer (1991) mentioned that lemon had 4.5% TA.

At the beginning of ripening process, its sugar/acid ratio was low, because of its low sugar content and a high acid content that made the fruit taste sour. During the ripening process, acids were degraded and sugar content increased

Table 2 Chemical composition of physalis fruits.

	Wet weight*	Dry weight*	DRIs• (g/day)	Value in 100 g fruit/ DRIs × 100
Moisture %	81.34 ± 1.59			
Energy kcal		49	Men: 2215••	2.2
			Women: 2025	2.4
Crude protein (N × 6.25) %	2.46 ± 0.18	13.18 ± 0.97	Men: 56•••	4.4
			Women: 46	5.3
Ether extract %	2.91 ± 0 .12	15.59 ± 0.13		
Total ash %		5.58 ± 0.52		
Reducing sugars %	2.19 ± 0.27	18.16 ± 0.93		
Non-reducing sugars %	1.72 ± 0.51	14.27 ± 0.86		
Total sugars %	3.91 ± 0.09	32.43 ± 0.77	130	3.0
Nitrogen free extract (NFE) %		17.24 ± 1.33		
Crude fibers %		5.78 ± 0.21	Men: 38	15.2
			Women: 25	23.1
Carotenoids (µg/g sample)	69.55 ± 0.70			
Polyphenols "as tannic acid" (mg/100 g)	82.00 ± 0.78	125.04 ± 0.56	1••••	8.2
Ascorbic acid (mg/100 g)	39.68 ± 0.15		Men: 90	44.1
			Women: 75	52.9
Pectin substances %		0.47 ± 0.09		

* Values are means of 3 determinations ± standard deviation.
• DRIs = Dietary Recommended Intakes for Adults (2004).
•• Based on 1.3 kcal/kg Body Weight/Hour for the reference body weight.
••• Based on 0.8 g/kg Body Weight/Day for the reference body weight.
•••• Duthie *et al.* (2000).

and thereby the sugar/acid ratio achieved a high value (11.27/1), which was higher to those of other fruits: mandarins (8/1), navel oranges (8/1), other oranges (7/1) and grape fruits (5.5/1) (McAlpine 1994). This sugar/acid ratio is considered as the main physico-chemical properties which give many fruits their characteristic flavor and is an indicator of commercial and organoleptic ripeness.

Physalis fruits contained a considerable amount of fibers (5.8% of dry weight), polyphenols (82 mg/100 g of wet weight) and vitamin C (39.7 mg/100 g of wet weight); whereas this amount covered approximately 17, 9 and 48 % respectively of Dietary Reference Intakes (DRIs).

Fruits contained 2.46% protein and 5.58% ash. Similar values were reported by Abou-Gharbia and Abou-Tour (2001) for *P. pruinosa* fruits 2.40% protein and 5.65% ash. However, these contents were higher than those reported by Morton and Miami (1987) for *P. peruviana* and USDA (2006) for *P. ixocarpa*, who found that physalis varieties contained 0.054-0.96% protein and 1.01-0.55% total ash. These values were higher than that found in apple (0.26, 0.19%), pear (0.38, 0.33%), watermelon (0.61, 0.25%), strawberry (0.67, 0.40%), peach (0.91, 0.43%), banana (1.09, 0.82%), kiwifruit (1.14, 0.61%) and avocado (2.0, 1.58%) (USDA 2006).

Its total lipid content in the pulp including seeds was very high for a fruit (2.91% wet weight) as found usually in fruits such as strawberry (0.30%), watermelon (0.15%), kiwifruit (0.52%), pear (0.12%), apple (0.17%), banana (0.33%), mango (0.27%) and peach (0.25%), but lower in avocado (14.7%) (USDA 2006). Moreover, its total sugar content is low (3.91% w/w) as found usually in others fruits strawberry (4.89%), watermelon (6.2%), kiwifruit (9.0%), pear (9.8%), apple (10.4%), banana (12.2%), mango (14.8%) and peach (8.4%).

Crude fibers reached (5.78% dw), which was close to that mentioned by Abou-Gharbia and Abou-Tour (2001) with 5.87% for *P. pruinosa*, but higher with that reported by Watt and Merrill (1963) for *P. pubescens*, Morton and Miami (1987) for *P. peruviana* and USDA (2006) for *P. ixocarpa* 2.8, 4.9 and 1.9%, respectively. It was higher than in others fruits such as watermelon (0.4%), peach (1.5%), strawberry (2.0%), apple (2.4%) and banana (2.6%) but it were lower than in raspberry (6.5%) and avocado (6.7%) (USDA 2006).

Pectin substances reached 0.47%, which was lower than that 1% reported by Abou-Gharbia and Abou-Tour (2001) for *P. pruinosa*. Compared with other fruits, Oecd (2003) stated that percentages of pectin substances were in apple (5-7%), banana (2-4%), carrot (7-18%), cherry (2-4%), orange and lemon (30%), strawberry (5%) and peach (8%).

Fruits contained 82.0 mg/100 g of polyphenolic substances as tannic acid, which was higher than that found by Abou-Gharbia and Abou-Tour (2001), 74.1 mg/100 g for *P. pruinosa*. Meanwhile, it was lower than the polyphenolic content in apricot, 162.4 mg/100 g (El Sheikha 2004).

Fruits contained a moderate amount of vitamin C (39.7 mg/100 g (w/w)), which was similar to that reported for *P. pruinosa* by Abou-Gharbia and Abou-Tour (2001) and higher than that presented by Watt and Merrill (1963) for *P. pubescens*, Cantwell *et al.* (1992) for *P. ixocarpa*, and USDA (2006) *P. ixocarpa*, being 11, 34 and 11.7 mg/100 g, respectively. It was also higher than that in other fruits such as apple (5 mg/100 g edible weight), avocado (15 mg/100 g), banana (5 mg/100 g), cherry (31 mg/100 g), grape (30 mg/100 g), mango (8 mg/100 g), peach (4 mg/100 g), pear (25 mg/100 g) and raspberry (7 mg/100 g). On the other hand, this content was lower than that in grapefruit (140 mg/100 g), lemon and orange (150 mg/100 g), strawberries (160 mg/100 g), blackcurrant (200 mg/100 g) and kiwifruit (155 mg/100 g) (Kirk and Sawyer 1991).

Fruits were very rich in carotenoids with 69.55 µg/g (w/w) which attributed their orange colour. This content was higher than that mentioned by Morton and Miami (1987) for *P. peruviana* (613 µg/100 g), as well as Abou-Gharbia and Abou-Tour (2001) for *P. pruinosa* (60 µg/100 g). It was the highest content in all of fruits and vegetables; i.e., pear (0.45 µg/g); apple (0.67 µg/g); kiwifruit (1.74 µg/g); peach (3.20 µg/g); mango (4.73 µg/g); apricot (13.06 µg/g); grapefruit (21.16 µg/g) and watermelon (48.35 µg/g) (USDA 2006). Raghava and Nisha (1990) also indicated that carotenoids are the main pigments of fresh physalis fruits.

Table 3 Physico-chemical properties and colour parameters of fresh physalis juice.

Property	Value
Physico-chemical properties *	
Total solids (TS) %	10.87 ± 0.14
Total soluble solids (TSS) %	10.65 ± 0.10
pH value	3.54 ± 0.005
Total titratable acidity (as anhydrous citric acid) %	1.43 ± 0.08
Sugar / acid ratio	7.59/1 ± 0.49
Colour parameters measured by Lovibond **	
Blue	2.1 ± 0.02
Yellow	35.0 ± 0.04
Red	6.6 ± 0.01

* Values are means of 3 determinations ± standard deviation.
** Values are means of 5 measurements ± standard deviation.

Table 4 Chemical composition of fresh physalis juice.

	Wet weight*	Dry weight*	DRIs• (g/day)	Value in 100 mL juice/ DRIs × 100
Moisture %	89.34 ± 0.14			
Energy kcal		16	Men: 2215••	0.01
			Women: 2025	0.02
Crude protein (N × 6.25) %	1.02 ± 0.24	9.11 ± 0.16	Men: 56•••	1.82
			Women: 46	2.26
Ether extract %	0.30 ± 0.02	1.61± 0.27		
Total ash %		7.01 ± 0.81		
Reducing sugars %	1.53 ± 0.07	20.10 ± 0.16		
Non-reducing sugars %	0.82 ± 0.22	10.78 ± 0.33		
Total sugars %	2.35 ± 0.18	30.88 ± 0.21	130	1.80
Carotenoids (µg/ mL juice)	70.01 ± 1.12			
Polyphenols "as tannic acid" (mg/100 mL juice)	76.62 ± 0.95	116.57 ± 0.76	1••••	7.66
Ascorbic acid (mg/100 mL juice)	38.77 ± 0.50		Men: 90	43.07
			Women: 75	51.69
Pectin substances %		0.23 ± 0.01		
Colour Index "as O.D. at 420 nm"	0.049 ± 0.005			

* Values are means of 3 determinations ± standard deviation.
• DRIs = Dietary Recommended Intakes for Adults (2004).
•• Based on 1.3 kcal/kg Body Weight/Hour for the reference body weight.
••• Based on 0.8 g/kg Body Weight/Day for the reference body weight.
•••• Duthie *et al.* (2000).

Physico-chemical properties of physalis juice

The fresh juice had the same colour as the fruit due to its very high carotenoids (70.0 µg/mL) contents. For example, cantaloupe juice contains only 7.6 µg/mL (Moustufa 2002), lemon (0.29 µg/mL), orange (3.23 µg/mL) and passion fruit juice (4.42 µg/mL). Yellow and red colours were the dominant fractions of fresh Physalis juice (**Table 3**). This type of colour was also found for *P. peruviana* (Raghava and Nisha 1990), for *P. ixocarpa* (Cantwell *et al.* 1992) and for *P. pruinosa* (Abou-Gharbia and Abou-Tour 2001).

The pH 3.54 of the fresh juice (**Table 3**) was higher than agrume juices (pH 2.3 for lime and pH 2.4 for lemon juices) while, it was close to that of pineapple (pH 3.2; Joslyn 1970) and orange juice (pH 3.6; Carvalho *et al.* 2006). Its total titratable acidity reached 1.43%. This was higher than that reported for lemon juice 1.15% (Joslyn 1970) but lower than in fresh mango juice (2.29% and 4.11%) (Zeid 1996).

It contained a considerable amount of polyphenols (76.6 mg/100 mL (w/w)) as tannic acid and vitamin C (38.77 mg/100 mL (w/w)) (**Table 4**); whereas this amount reached approximately 8 and 47%, respectively, of DRIs. It was lower than that of fresh apricot; i.e., 150.30 mg/100 mL and 0.55%, respectively (El Sheikha 2004).

The juice contained 89.3% moisture (**Table 4**) as many others juices as cantaloupe juice (91.5%, Moustufa 2002), grapefruit (90%), lemon (90.7%), lime (90.7%), orange (88.3%) and tangerine (88.9%) juices but this moisture was higher than that of fresh mango (80.9%, Zeid 1996) or passion fruit (85.62%) juices (USDA 2006).

It contained a high amount in total soluble solids (10.65%) and its sugar/acid ratio (7.59/1) (**Table 3**) was higher than that in fresh cantaloupe juice (8.35%, 2.07/1) (Moustufa 2002) while, it was relatively lower than that reported for fresh mango juice (18.2%, 7.95/1) (Zeid 1996). Its total solids reached 10.87%, which was relatively higher than that reported in fresh cantaloupe juice 8.51% (Moustufa 2002); whereas it was lower than that (19.1%) in fresh mango juice (Zeid 1996).

Its total sugars content (2.35% (w/w)) was higher than lime juice (1.69%). Meanwhile, it is lower than orange (8.40%), tangerine (9.90%) and passion fruit juices (13.40%) (USDA 2006).

Physalis juice was rich in mineral (total ash = 7.01%). It had high contents of potassium (1196 mg/100 mL), phosphorus (587 mg/100 mL), calcium (70 mg/100 mL), sodium (35 mg/100 mL), magnesium (19 mg/100 mL), zinc (2.4 mg/100 mL), copper (1.5 mg/100 mL), iron (1.2 mg/100 mL) and manganese (0.6 mg/100 mL) (**Table 5**). For example, its potassium content was ten time higher than potassium content in juices as lime (117 mg/100 mL), lemon (124 mg/100 mL), grapefruit (162 mg/100 mL), tangerine (178 mg/100 mL) and orange (200 mg/100 mL) (USDA 2006). Furthermore, Physalis juice had a good level of boron (1 mg/100 mL) comparing with grape juice (2.06 mg/100 mL) as the best source of boron in fruit juices (Hunt and Herbei 1991; Anderson *et al.* 1994). TSS 13.5% was relatively lower than that of *P. pubescens* fruits (14.6%, Watt and Merrill 1963) and higher than that of *P. pruinosa* (10%, Ahmed 1989). Meanwhile, it was close to that stated by Cantwell *et al.* (1992) for *P. ixocarpa* fruits (12.5%) as well as Abou-Gharbia and Abou-Tour (2001) for *P. pruinosa* (13%).

It was poor in protein (1.02%) but it had a high nutritional value compared to egg protein because of its relatively high content in essential amino acids and its good digestibility. Protein content was higher than cantaloupe (0.69%) (Moustufa 2002), lemon (0.38%), lime (0.50%) and orange

Table 5 Minerals content of fresh physalis juice comparing with DRIs.

Minerals	Mineral content (mg/100mL juice)	DRIs* for adults (mg/day)	Value in 100 mL consumed juice / DRIs × 100
Major			
Potassium	1196	4700	25.4
Phosphorus	587	700	83.6
Calcium	70	1000	7
Sodium	35	1500	2.3
Magnesium	19	Men: 400	4.8
		Women: 310	6.1
Trace			
Zinc	2.4	Men: 11	21.8
		Women: 8	30.0
Copper	1.5	0.9	166.7
Iron	1.2	Men: 8	15
		Women: 18	6.7
Manganese	0.6	Men: 2.3	26.1
		Women: 1.8	33.3
Ultratrace			
Boron	1	1–13**	7.7–100

* DRIs = Dietary Recommended Intakes for Adults (2004).
** As stated by Wardlaw and Kessel (2002).

Table 6 Amino acids content in fresh physalis juice.

Amino acids	Content (g/100 g protein)	FAO pattern* (g/100 g protein)		
		Child 2-5 years	Child 10-12 years	Adult
Isoleucine	4.236	2.8	2.8	1.3
Leucine	4.968	6.6	4.4	1.9
Lysine	4.762	5.8	4.4	1.6
Cysteine	1.291	–	–	–
Methionine	1.694	–	–	–
Total sulfur containing amino acids	2.985	2.5	2.2	1.7
Tyrosine	1.066	–	–	–
Phenylalanine	2.585	–	–	–
Total aromatic amino acids	3.651	6.3	2.2	1.9
Threonine	3.377	3.4	2.8	0.9
Tryptophan	3.893	1.1	0.9	0.5
Valine	3.927	3.5	2.5	1.3
Total essential amino acids	31.799	32.0	22.2	11.1
Histidine	3.223	–	–	–
Arginine	2.787	–	–	–
Aspartic acid	14.469	–	–	–
Glutamic acid	13.185	–	–	–
Serine	3.545	–	–	–
Proline	18.296	–	–	–
Glycine	5.532	–	–	–
Alanine	7.163	–	–	–
Total non-essential amino acids	68.20	–	–	–

* FAO/WHO/UNU pattern (1985).

Table 7 Essential amino acids content in fresh Physalis juice comparing with RDAs*.

Essential amino acids	Content (mg/100 mL juice)	RDAs (mg/day)*			Value in 100 mL consumed juice / RDAs × 100		
		2–5 years	10–12 years	Adult	2–5 years	10–12 years	Adult
Isoleucine	42.97	403	784	580 – 720	10.66	5.48	5.97 – 7.41
Leucine	50.39	949	1176	812 – 1008	5.31	4.28	5.00 – 6.21
Lysine	48.30	832	1232	696 – 864	5.81	3.92	5.59 – 6.94
Methionine + cysteine	30.28	351	616	754 – 936	8.63	4.92	3.24 – 4.02
Phenylalanine + tyrosine	37.03	897	616	812 – 1008	4.13	6.01	3.67 – 4.56
Threonine	34.26	481	784	406 – 504	7.12	4.37	6.80 – 8.44
Tryptophan	39.83	162.5	92.4	203 – 252	24.51	43.11	15.81 – 19.62
Valine	39.83	494	700	580 – 720	8.06	5.69	5.53 – 6.87
Total	322.56	4576	5992	4872 – 6048	7.05	5.38	5.33 – 6.62

* RDAs = Recommended Dietary Allowances (1989).

juices (0.70%) (USDA 2006).

Essential amino acids as Leu, Lys, Ile, Val, Try, Ser, Thr were either higher than those recommended by FAO/WHO/UNU (1985). Pro, Asp, Glu, Ala and Gly were the major amino acids (**Tables 6, 7**). Aromatic Amino acids (Tyr and Phe) were found to be the first limiting amino acid with a CS of 57.9%, while Leu and Lys represent the second and the third limiting amino acids with 75.3 and 82.1%, respectively. CS, EAAI and PER scored 58, 73.48 and 1.68, respectively comparing with the egg protein (100, 100 and 3.8) stated by (Schaafsma 2000). Comparing with amino acids indices of apricot juice reported by El Sheikha (2004), who found that, each of Asp, Glu, Try and Ala were the major amino acids. Considerable amounts of Leu, Pro, Ile and Val were also found in fresh apricot juice. Lys was found to be the first limiting amino acid, while aromatic amino acids (Tyr and Phe) and sulfur amino acids (Cys and Met) represented the second and third limiting amino acid, respectively. The CS, EAAI and PER were 42, 58.75 and 1.53, respectively.

Ascorbic acid (38.77 mg/100 mL) contents were higher than those of cantaloupe (37 mg/100 mL) (Moustufa 2002), passion fruit (29.80 mg/100 mL), lime (30 mg/100 mL) and tangerine (31 mg/100 mL) juices but it had lower content then in lemon (46 mg/100 mL) and orange juices (50 mg/100 mL) (USDA 2006).

Twelve phenolic fractions were indentified in methanolic extract of fresh juice (**Table 8**). The major phenolic compounds in the fresh juice were catechin, salicylic, para-coumaric, and chlorogenic acids. The predominant compounds were phenols followed by ferulic acid. In the other hand, El Sheikha (2004) stated that, the major compound of fresh apricot juice phenolic fractions were ferulic, salicylic and chlorogenic acids, where the predominant compound was resorcinol.

Table 8 Phenolic compounds in methanolic extract of fresh physalis juice obtained by HPLC.

Phenolic compounds	Contents (µg/100 mL juice)
Protocatechic acid	0.932
Para-hydroxybenzoic acid	0.561
Chlorogenic acid	2.086
Catechin	4.968
Phenol	15.605
Vanillic acid	2.727
Para-coumaric acid	5.368
Ferulic acid	10.036
Salicylic acid	7.341
Rutin	0.449
Coumaric acid	0.176
Myricetin	0.104
Pyrogallic	ND*
Hydroquinone	ND
Gallic acid	ND
Resorcinol	ND
Ortho-coumaric acid	ND
Cinnamic acid	ND
Quercetin	ND
Kaempferol	ND

* ND = Not detected

Table 9 Antimicrobial assay of methanolic extract obtained from fresh physalis juice.

Microorganisms	Disc diffusion assay (zones of inhibition, neat in mm)*	
	Phenolic concentrations (%)	
	15	30
E. coli	10	10
B. subtilis	NI**	8
C. albicans	NI	NI
F. solani	67.0	90

* Zones of inhibition = Measurements including disc diameter (6 mm).
** NI = No Inhibition observed at any time.

Antimicrobial activity of juice methanolic extracts

Bacillus subtilis, *Fusarium solani*, *Escherichia coli* O157:H7 and *Candida albicans* are the microbes which cause a variety of spoilage in juices that could affect human health (Hilborn *et al*. 2000; Health Notes 2002). Both concentrations of methanolic extract (15 and 30%) obtained from fresh physalis juice, showed a significant antimicrobial activity against *E. coli* O157:H7 and a complete antimicrobial activity against *F. solani* (**Table 9**). A resistance of *B. subtilis* to the lower concentration (15%) of the same methanolic extracts was also observed. On the contrary, methanolic extract of physalis juice at both concentrations had no antimicrobial effect against *C. albicans*.

CONCLUSIONS

This paper presents one of the first complete analyses of physalis fruits. Physalis fruits were interesting fruits in term of their chemical composition. Our results were similar to those obtained by authors on similar species. The composition was, of course, affected by the origin zones, variety, cultivars and climatic factors. Physalis fruit and juice are acidic and high in its nutritive value, were rich in polyphenols, carotenoids which were responsible for their orange colour and contained moderate amounts of vitamin C and lipids. They contain a low amount of proteins. Moreover, physalis juice had high contents of potassium, phosphorus, calcium, sodium, magnesium, zinc, copper, iron, manganese and boron. These minerals play major roles as constituents of bone and teeth and soluble salts help to control the composition of body fluids, assisting enzyme functions as coenzymes and other important functional components including hormones and vitamins. It could be a good potential source of essential amino acids except for Tyr and Phe, Leu and Lys.

In addition, we tested some methanolic extracts which contained phenolics, flavonoids and other polar molecules for their antimicrobial activity against pathogenic microorganisms. The antimicrobial activity of these extracts was significant against *E. coli* O157:H7 and *Bacillus subtilis*, complete against *Fusarium solani* and had no effect against *Candida albicans*.

All these results and its potential nutraceutical quality could participate in the development of *Physalis* as a commercial crop of economical utility.

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